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ABSTRACT

The Educational Leaders in Mathematics (ELM) Project was a five-stage experimental design to assist elementary and secondary inservice teachers in developing a constructivist view of learning as a basis for designing and implementing instruction in mathematics. Teachers participating in a 2-week summer institute experienced the role of mathematics students engaged in the construction of mathematical concep s. They also examined children's learning of mathematics through the viewing and discussion of videotapes. The second stage extended this work through a structured program of classroom follow-up and support. Assuming that transfer of learning to the classroom occurs most predictably where demonstration, feedback and coaching are components of the teacher education process, consultants observed participants' classroom behaviors and provided feedback and suggestions. A discussion is presented on the success of the first to stages of the program in changing teacher behaviors and implementing innovation in the classroom. (JD)

THE IMPACT OF INTENSIVE CLASSROOM FOLLOW-UP IN A CONSTRUCTIVIST MATHEMATICS TEACHER EDUCATION PROGRAM

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Background

The Educational Leaders in Mathematics (ELM) Project[1] at Mt. Holyoke College was a five-stage experimental design to assist inservice teachers in developing a constructivist view of learning as a basis for designing and implementing instruction in mathematics. ELM involved both elementary and secondary teachers. The first two stages of the Project (one calendar year) are reported on here for the purpose of this symposium. The first stage was the SummerMath for Teachers institute . The second stage extended this work through a structured program of classroom follow-up and support.

Program Structure

Stage One: the Summer Institute. Two two-week institutes (one for elementary and one for secondary) provided an introduction to mathematics instruction from a constructivist perspective. Participating teachers experienced the role of mathematics student engaged in the construction of mathematical concepts (as described in Monk & Stimpson 1989). They also examined children's learning of mathematics (similar to Loef et al. 1989) through the viewing and discussing of videotapes as well as their own audiotaped interviews with students. They worked on their ability to ask probing questions and to design sequences of lessons which encourage student construction of key math concepts.

Stage Two: the Academic Year Follow-up. Teachers participated in the follow-up program from September through May subsequent to their involvement in the Summer Institute. An ELM staff member met on a weekly basis with each participating teacher in that teacher's classroom during and after class. During the mathematics class, the staff member either observed the teaching of the participating teacher or provided demonstration teaching. Following the mathematics class, the teacher and ELM staff member met to discuss what happened during the mathematics lesson, to informally evaluate the learning, and to discuss possible next steps. Participating teachers also met with their ELM colleagues and Project staff in four workshops in which further work was done on developing instruction and during which discussions took place between teachers about implementation successes and difficulties. (A detailed description of the content and structure of the ELM Project is found in Simon and Schifter, 1989.)

Theoretical Basis for Classroom Follow-up

The theoretical basis for classroom follow-up is in part a result of research on teacher change in general and in part a result of the particular demands of assisting teachers in developing a constructivist view of instruction and in implementing instruction consistent with that view.

Teacher change. Joyce and Showers (1988) in summarizing their own research and recent literature concluded that "transfer of learning" [to the classroom] occurs most predictably where demonstration, feedback and coaching are components of the teacher education program. They asserted,

> Coaching appears to be most appropriate when teachers wish to acquire unique configurations of teaching pattern and to master strategies that require new ways of thinking about learning objectives and the processes by which students achieve them. (P.84)

Hall and Loucks (1977) demonstrated that the implementation of classroom innovation does not take place all at once.

> First use is typically disjointed, with management problems quite common. With continued use management becomes routine, and the user (teacher or professor) is able to direct more effort toward increased effectiveness for the clients (learners) and integrate what (s)he is doing with what others are doing. Obviously, these advanced levels of use are not attained merely by use of the innovation through several cycles. Experience is essential but not sufficient to insure that a given individual will develop high-quality use of an innovation.

The researchers went on to emphasize the importance of support for the innovation "extended across several cycles of use."

Change towards constructivism. While teacher inservice programs typically promote changes in teaching strategies (behaviors), the primary focus of ELM was to influence teachers' basic view of how mathematics is learned. Development of a constructivist view of learning as a basis for instruction implies sweeping and fundamental changes for most classroom teachers. Such a shift in belief about learning and learners has the potential to cause a redesign of the classroom learning activities (NCTM, 1989), a redefinition of the roles of the teacher and the students (Cobb, Yackel, & Wood, 1988; Lampert, 1988), a modification of the social climate and the nature of discourse (Lampert, 1988), a revision of the "contrat didactique," the implicit didactical contract between teacher and students, (Brousseau, 1986), a realignment of the mathematics curriculum (NCTM, 1989), and the creation of new modes of assessment (Romberg & Zarinnia, 1987).

Initial steps in the direction of constructivism need not be nearly so extensive. However, a teacher who undertakes such a fundamental and potentially far-reaching change could be easily overwhelmed without competent and regular support.

Teachers' constructions. ELM's programmatic model of learning went beyond the idea that learners need to construct their own understandings of mathematics. It carried over to the view that teachers need to construct their own personally meaningful understandings of mathematics learning and teaching. Just as the mathematics teacher selects experiences designed to maximize the students' construction of powerful ideas, ELM staff (in the summer institute) selected experiences for teachers designed to lead to powerful constructions about learning and teaching.

The relationship of ELM staff members to the teachers changed from teacher in the institute to teacher/resource person in the follow-up program. The staff member still endeavored to facilitate teachers' constructions, but at the same time was now responsible to a greater extent for directly providing ideas, resources, and feedback to teachers as needed.

Results of the ELM Follow-up Program

Academic year 1985-86 was the pilot year of ELM with fourteen teachers completing Stage Two. In the first full year, 1986-87, twenty-nine teachers completed Stage Two. (One teacher dropped out expressing that her participation was not worthwhile.) In 1987-88, twenty-nine teachers completed Stage Two. (One dropped out because of family illness.) Data described below are from the two full years of the program. In each year of ELM, teachers participated in the program on a voluntary basis and represented both elementary and secondary schools (in approximately a 2:1 ratio).

The follow-up program provided four types of data: (1) teachers' evaluations and comments on the follow-up program, (2) measures of the effectiveness of the first year of ELM (summer institute and follow-up program), (3) elaboration of the role of the classroom consultant, and (4) identification of common difficulties in implementing instruction based on constructivism.

<u>(1) Teachers' evaluations and comments on the follow-up program.</u> Participating teachers completed an anonymous questionnaire designed to obtain their perceptions of the follow-up program. Several open-ended questions were followed by a set of Likert-style items. Teachers responded to each of these items either strongly agree, agree, neutral/undecided, disagree, or strongly disagree. Average scores for each question were obtained by translating these responses into a score from 1 to 5. A score of 5 indicated that they strongly agreed. Half of the items were negatively worded on the questionnare and their scores reversed. The items and responses appear below. Each item is followed by the median and then the mean. Items referring to the effectiveness of staff members involved have been omitted.

-The follow-up program has helped me become a more effective teacher. 5, 4.6
-The follow-up program has taken been an effective use of my time. 5, 4.5
-The follow-up program has caused me anxiety. 3, 2.9
-The follow-up program has increased my enjoyment in teaching mathematics. 5, 4.6
-The follow-up program is having a positive effect in subject areas other than math. (Put N/A if you teach only math). 5, 4.4
-The follow-up program has increased my confidence as a mathematics teacher. 5, 4.5
-Demonstration teaching by my follow-up program consultant has been helpful to me. 4, 4.0
-The follow-up program has allowed me to clarify what I learned in SummerMath for Teachers. 4, 4.4
-The visitations have not disrupted my classroom teaching. 5, 4.5
-What I am working on with my consultant is relevant to my goals in teaching mathematics. 5, 4.5

It should be noted that, although it was not the intention of the program to cause anxiety or to decrease confidence, a small amount of anxiety may have had a positive effect on implementation efforts, and a decrease of confidence in the case of complacency may have been appropriate.

The high ratings were supported by the teachers' responses to open-ended questions. One teacher combined thoughts expressed by many. She wrote,

> In looking back over the past year, I feel that my math program and the way I teach has changed dramatically.
>
> The hardest thing has been to let go. To let go of the math book and my traditional way of teaching and to try this approach sometimes put fear into me. Fear that it would not work and worry that

> I might somehow fail my class and not give them a good foundation, that is so important in first grade.
>
> Having Mary come in each week, with her knowledge, experience, confidence, and encouragement, gave me the support I needed to grow in this direction....She helped me to analyze each lesson - why some things worked while other things did not work. Her help was vitally important. I am sure without it, I could not have implemented this way of teaching.
>
> As weeks went by, I came to realize that with thoughtful preparation beforehand, challenging problems, the use of manipulatives and Mary's weekly consultations, I was becoming more comfortable teaching this way. I could see my class's math ability grow and by their verbalizations, I could tell what they were understanding or what concepts were confusing to them.

One exception to the highly rated questionnaire responses was "The follow-up program has caused me anxiety." Responses were bimodal for "agree" and "disagree."

<u>(2) Measures of the effectiveness of the first year of ELM (summer institute and follow-up program).</u> ELM researchers endeavored to distinguish between teachers' implementation of instructional strategies based on experiences in ELM and teachers' development of a constructivist view of learning as a basis for their instructional decisions (Simon & Schifter, 1988). The former was designated "strategies" and the latter "epistemology." While the implementation of strategies modeled in ELM was viewed as a significant step, it is the development and use of a constructivist view of learning that was the principal objective of ELM.

To assess implementation of strategies, ELM adapted the Levels of Use (LoU) measure, developed by Hall et al. (1975). LoU, through structured interviews, assesses the degree to which an innovation has been implemented. The instrument is designed to evaluate use of innovations which are changes in instructional strategies.

The challenge of assessing the use of a constructivist epistemology required rethinking some of the fundamental assumptions behind the LoU instrument. As a result, the ELM researchers developed a new measure, modeled after the LoU with parallel levels, called the Assessment of Constructivism in Mathematics Instruction (ACMI). ACMI was based on the specific considerations of developing a constructivist view as a basis for instructional decision making and design. This assessment required an explicit, working definition of constructivism which would allow a determination to be made as to whether teachers' decision-making was based on a constructivist view. The following two-part definition was adopted:

1. Constructivism is a belief that conceptual understanding in mathematics must be constructed by the learner. Teachers' conceptualizations cannot be given directly to students.

2. Teachers strive to maximize opportunities for students to construct concepts and minimize teacher telling and student memorization and imitation. This suggests not only a perspective on how concepts are learned, but also a valuing of conceptual understanding.

A description of the ACMI and a discussion of the rationale behind it are included in Simon and Schifter, 1989. Both the LoU and the ACMI involve structured interviews with teachers. Scoring of the interviews involves determining the level of implementation for each.

LoU and ACMI ratings from the two full years of the project (data collected in Spring 1987 and 1988) are discussed here. Data from the pilot year is not included because of the smaller number of teachers and because the pilot year was a developmental year for the assessment instrument as well.

LoU results (See Table 1.) indicated that 98% of the teachers who completed the classroom follow-up implemented at least one of the principal strategies modeled in ELM (see Table 2) while 52% (Level IVb) internalized the innovation to a degree where they could adapt the innovation to the specific needs of the learner.

ACMI results (See table 3.)indicated that 64% of the ELM teachers showed evidence of at least a rudimentary constructivist view of learning as the basis for their teaching. 41% of the teachers reached Level IVb, which indicates that they have progressed beyond generalized implications for teaching to a level where they consistently build their instruction on the current understandings of the students.

TABLE 1.
SUMMARY OF LOU RESULTS
(Strategies)

Level		#	(%)
O	Nonuse	1	
III	Mechanical use	10	(98%)
IVA	Routine	16	(80%)
IVB	Refinement	21	(52%)
V	Integration	8	(14%)
	n=56		

refers to the number of teachers at that level.
(%) refers to the percent of teachers at that level or higher.
Based on interviews in the spring of 1987 and 1988.

TABLE 2.
STRATEGIES MODELED IN ELM

1. Using non-routine problems
2. Exploring alternative solutions
3. Asking non-leading questions
4. Using manipulatives, diagrams, and alternative representations
5. Having students work in groups and pairs
6. Pursuing thought processes on both "right" and "wrong" answers
7. Working with Logo
8. Employing wait time
9. Encouraging student paraphrasing of ideas expressed in class

TABLE 3
SUMMARY OF ACMI RESULTS
(Epistemology)

Level		#	(%)
O	Nonuse	20	
III	General beliefs, struggling to implement	6	(64%)
IVA	Stable approach to instruction	7	(54%)
IVB	Responsive to student learning	21	(41%)
V	Assists or collaborates with colleagues	2	(4%)
	n=56		

refers to the number of teachers at that level.
(%) refers to the percent of teachers at that level or higher.

Based on interviews in the spring of 1987 and 1988.

(3) Elaboration of the Role of the Classroom Consultant

A basic structure for the role of the classroom consultant was created when the ELM Project was initially conceived. The actual elaboration of that role was a result of practice, negotiation of the role with participating teachers, and feedback from teachers. The functions served by the classroom consultant can be sorted into five categories as follows:

1. Structure and accountability. Even though the consultants' role was non-evaluative, the weekly nature of the follow-up caused teachers to feel compelled to work regularly on the ELM-related objectives that they had established for themselves.

> [I liked best] the "weekliness" of it. It maintained or sustained the summer enthusiasm throughout the year. I kept thinking about SummerMath ideas and did not let the momentum of daily life tie me down.
>
> It worked against my slipping into more familiar and comfortable old habits.

2. Support. Teachers valued the support that they received from the consultant which took several forms,

a) encouragement to continue,

b) a sounding block to air feelings that accompanied implementation efforts,

c) the feeling of being part of a team working on instructional improvement (not being alone in this effort),

d) a partial remedy to the professional isolation that many teachers experience.

Teachers commented:

> I enjoyed having someone to discuss my anxieties about teaching math.
>
> continual support and encouragement from consultant
>
> It was great having someone to talk to and try and work out any problems I was having and where to go from there.
>
> Harvey was invaluable for my morale, keeping things in perspective, "support."
>
> ...both supportive and challenging - that seems to be a paradox but it is none the less representative of my feeling. I felt safe failing, although I was uninterested in doing so.
>
> I felt that a "we" was developed. "We" had success or "we" failed. We were a team.
>
> Sharing our ideas and frustrations and joys.

> ...reinforcement that another adult was seeing what I saw happening.
>
> I liked having someone encourage me to continue even when I didn't think I was succeeding.

<u>3. Demonstration teaching.</u> Teachers valued the opportunity to see the consultant teach in their classes.

> [I liked best] the opportunity of seeing theory actually being put into practice. To be able to observe teaching strategies and modifications in the classroom was most helpful.
>
> Her demonstration lessons were interesting in-and-of themselves, and they allowed me to observe specific pupil behaviors and interactions.

<u>4. Resource.</u> The consultant was a source of ideas and materials and a link with other resource people and organizations.

> I also appreciated the extensive help she gave me in <u>my</u> understanding of certain math concepts
>
> ...someone who really knows child development
>
> a chance to brainstorm "next steps"
>
> Having someone to bounce ideas off of and to supply resource materials
>
> She made suggestions which helped me to generate more pupil inter-participation. This was of infinite value.
>
> Mary helped me with ways to approach concepts, The ideas were practical and very helpful. She brought books and materials which were also helpful.

<u>5. Encouraged reflection.</u> Consultants provided a regular opportunity for teachers to reflect on mathematics learning and teaching.

> ...someone who could objectively ask me questions that clarified my goals
>
> We spent much of the discussion time figuring out where the students were having difficulties...He related what the student(s) had done so I could concentrate on why. Then I understood what the behavior indicated, and could begin to think about how to deal with it next time.
>
> I found our conversations the most interesting classroom analysis I have ever done. I felt pushed to understand what I as a teacher was trying to do and what I actually did. You were able to point out to me (or get me to notice) times when I did things without conciously planning them which did or did not support my stated goals.

6. Source of feedback. Consultants provided the teacher with another point of view in examining classroom lessons.

> Terry gave me specific, relevant feedback in terms of her observations of the lesson in general, and pupil behaviors which she was able to observe.
>
> ...the positive feedback I received from her. She found good points even in what seemed like disasters.

Several of the teachers provided feedback that the weekly structure of the follow-up program had a significant disadvantage as well. Because the consultant was never in one classroom for several days in a row, they were never able to be directly involved in following through a sequence of lessons on an important idea.

(4) Identification of Common Difficulties in Implementing Instruction Based on Constructivism

During weekly visitations, consultants explored with teachers obstacles that the teachers faced as they endeavored to implement their new learnings. Some of these obstacles seemed particularly noteworthy since they were experienced by a number of teachers working with various classroom consultants. Awareness of these difficulties can inform future teacher education efforts.

Time pressure. Teachers found that, at least initially, allowing students to construct understandings required more time than telling and showing to "cover the same amount of material." At times this pressure was institutionalized or coming from parents. At other times, it was self-imposed by teachers.

Textbook organization. Most of the ELM teachers found themselves to be less dependent on the textbook than they had been before entering ELM. However, textbooks were still used to articulate the sequence of mathematical topics to be taught and to assign problems. The textbooks, by and large, were procedurally rather than conceptually oriented, they were not organized around "big ideas" and neglected the rich web of interconnections among mathematical ideas. As a result, attempts to integrate new approaches with the existing textbooks were often problematic.

Student Resistance: Students (particularly the older students) often had become comfortable with the teacher showing and telling and the students imitating and memoriziing. Attempts to actively involve students in developing understandings were often greeted with, "Why don't you just tell us how to do it?" Helping students to change their conceptions of mathematics, their views of learning, and their expectations of mathematics class was a serious challenge and one which led at times to frustration. The teacher who is experienced in teaching from a constructivist perspective might be able to anticipate student resistance, sometimes preempt it, and work for change. ELM teachers who were teaching from this perspective for the first time were not always prepared to deal with student resistance. What's more they were hard-pressed to sort out general resistance to changes in the classroom dynamics from difficulties caused by particular instructional weaknesses.

Jane's geometry class provides an example of this latter difficulty. Jane's geometry students were complaining a great deal about not knowing when an idea was correct. Jane had observed that her students had not learned to think independently nor to evaluate or justify mathematical ideas. Jane expressed that it was difficult for her to distinguish whether the substantial resistance on the part of the students was because they were being pushed to think more independently or whether she was not helping them to reach a sense of "knowing."

<u>Holes in students' mathematical foundations.</u> ELM teachers reported regularly that one effect of their participation in the program is that they listen to students more and probe further into what students understand and don't understand. As a result they "see" weaknesses that were not apparent before. Their students seem to be missing foundational concepts as well as problem solving savvy. As a result, teachers often recognized that students needs were more in line with the curriculum of previous courses than with the current course. Many of these teachers felt a tension between what they knew their students needed and what they were expected to teach. In extreme cases, the current course was not at all appropriate for the mathematical level of the students.

<u>Teachers' weaknesses in mathematics.</u> ELM teachers have reported that their own lack of understanding and inability to see many of the connections between concepts limit their implementation

efforts. In addition, in the judgement of the ELM staff, teachers' narrow conceptions of mathematics and lack of understanding of how mathematical knowledge is developed and how it is applied also restricted implementation efforts. This is consistent with other studies (Ball, 1988; Bergeron & Herscovics, 1988).

Consistency versus first steps. As discussed earlier, the changes that can follow from the development of a constructivist view of learning are extensive, far more than a teacher would be wise to take on initially. It is therefore important that the teacher choose an appropriate level of change with which to begin. Teachers who take on too much are likely to give up completely.

This choice of first steps however is complicated by the complexity of the system to be changed. If first steps do not go far enough, then a lack of consistency can undermine progress. An example is the teacher who decides that students will explore the concepts in a hands-on way for the first few days of a new unit. However after that time, to "make sure that students are getting what they are supposed to" the teacher summarizes what the students should have learned and assigns textbook practice problems. The students soon learn that they can have an enjoyable social time for a few days and just pay attention when the teacher summarizes.

Emotional load of being a novice. Although the teachers averaged more than ten years experience, many expressed feeling like novice teachers, because their new modes of instruction were such a departure from what they had been doing before. Although there was an excitement that accompanied the newness, there was also the discomfort of intermitant failure and confusion. For the most part, such discomfort had not been a part of the comfortable routines that they had developed over years of teaching.

Lack of appropriate curriculum materials. Because instruction based on constructivism was such a departure from the status quo, teachers found themselves with few curriculum materials which really lent themselves to such instruction. As a result, teachers had the double burden of being novices, working out changes in instruction, while having to design most of the lessons that they would use.

CONCLUSIONS

Even though having the consultant in the classroom was somewhat anxiety provoking for about half of the teachers, ELM teachers indicated that they valued highly the opportunity to receive classroom follow-up. In order to apply a similar model elsewhere, aspects of the ELM follow-up which contributed to teachers' positive evaluation of the program must be considered. Three aspects seem particularly important. First, teachers participated in the program on a voluntary basis. Second, the classroom consultants were not involved in any evaluation of the teachers. Third, the teachers felt in control of the direction which their work with the consultant took.

ELM results suggest that the combination of the summer institute and the academic year follow-up have a profound effect on many of the participating teachers. As expected, teachers' strategies were more readily changed than the epistemological basis of their teaching. However, evidence from the ACMI indicated that ELM significantly affected the way 41% of the teachers thought about learning and the way they made decisions about teaching. ELM offers an existence proof that such changes can be brought about in experienced teachers in one year's time, albeit by a labor- and cost-intensive intervention.

Monk and Stimpson (1989) reported on the impact of opportunities for teachers to construct mathematical understandings. An important component of this work is the modeling provided by the teacher educators which contributes to a reorganization of teachers views of mathematics teaching. Loef et al. (1989) demonstrated the effect of having teachers focus on students' learning of mathematics. The ELM institutes combined both of these areas of study.

The follow-up program continued this work by providing additional modeling, this time with real students in real classrooms. It also furthered the reflection on student learning as consultants facilitated teachers' reflections on students' expressions of their mathematics. Not only did teachers try to make sense of evidence of student learning, but they were forced to consider whether they had gathered appropriate evidence for evaluating learning.

ELM demonstrated the key role that the classroom consultant played in the teachers' move towards constructivism. The role of the consultant emerged as a complex one, involving both cognitive and affective support for the process of change. The diversity of functions that the consultant served would generally be unavailable in the typical school system. It was not only the support services, but also the regularity provided by the structure of ELM that proved to be important. It further suggests that the changes called for by organizations such as the National Council of Teachers of Mathematics in their Curriculum and Evaluation Standards for School Mathematics (1989) will require efforts which go beyond the scope of the usual teacher inservice programs. A more ideal type of support would combine the ongoing nature of the ELM support with the flexibility to support teachers through whole units at key points in their efforts.

Finally the close working relationship of the ELM consultants with the classroom teachers allowed the Project to identify a number of the obstacles which impede the success and rate of progress of implementation efforts. ELM consultants were able to help teachers with some of these obstacles. However, many of them will require other types of solutions including changes in district expectations of teachers, development of appropriate curriculum materials, and mathematics courses for teachers which also work from a constructivist perspective.

The National Council of Teachers of Mathematics (NCTM, 1989) in its Curriculum and Evaluation Standards for School Mathematics, and the National Research Council (1989) have asserted that the learning of mathematics is a process of active construction on the part of the learner. They have called for major changes in mathematics education consistent with a constructivist view of learning. However, they have stopped short of giving a vision for teacher education that will prepare teachers to make these changes. The ELM follow-up program provides a model of the kind of ongoing support that must be provided if the envisioned changes are to be realized.

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